FPGA Implementation Of Efficient And High Speed Template Matching Module

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***Abstract*—Template Matching is a digital image processing technique used in classifying objects. Due to changing intensity and template size the computational complexity increases. In our project we have simplified the original normalized cross-correlation(NCC) algorithm and designed a parallel processing pipelined architecture circuit to improve the computational speed and accuracy .This template matching module can be used in all types of vision applications, pattern recognition ,face recognition and elastic matching for service.**

***Keywords*- Image processing, mean, normalized cross-correlation ,template matching.**

I. INTRODUCTION

Inspection is the main criteria in quality control of products in manufacturing industries. Since quality control is critical 100% inspection is required . The key concept of inspection is classifying objects and locate the object under inspection. For locating the objects , a number of methods have been implemented. One such method is Normalized Cross Correlation which is one of the most popular method used in image matching.

Template is a part of the image which is under inspection. The template matching is a technique in the digital image processing for finding the small parts of an image which actually match with a template image. The template image is always smaller than the source image.

This technique is used in manufacturing industries as a part of quality control, to detect the defects. This method can also be used to detect the edges in images. The main idea in this technique is to slide an image template over the source image(binary images or gray scale images). The binary images are the bit map images that is it is represented by only 0's and 1's.0 represents lower value black and 1 represents the higher value white . In Gray scale image the scale is represented by 0,1,…,255 where 0 represents the lower bit (black) and 255 represents the higher bit (white) and the remaining values represent the intensity and brightness levels of the patterns.

Template matching technique compares portions of images with one another. The sample image can be used to recognize similar objects in the source image. If the standard deviation of the template image compared to the source image is small enough then only the template matching can be used. This technique is more often used to identify printed characters, numbers and other small and simple objects.

In matching techniques one of the method used is the cross correlation. Cross correlation is a measure of two waveforms as a function of time-lag applied to one of them. This is also known as a sliding dot product. It is commonly used for searching a long signal over a shorter known feature. It is widely used as an effective similarity measure in matching tasks. However these methods are limited to some short baseline case.

Many matching algorithms have been proposed in the literature [8,10]. Matching of any two images with a large camera motion such as significant rotation and scale changes still remains a difficult task. In this project work a new correlation based method for matching two images with large camera motion is proposed.

Template matching technique requires a separate template for each scale and orientation since the template which represents the object as we expect to find it in the image can indeed be scaled or rotated.

The templates are quite sensitive to noise and occlusions. Template matching becomes too expensive especially for larger templates.

Some of the approaches to resolve these problems are as follows:

- A possible solution is to reduce the size of the templates and detect a set of local salient features in the image that are invariant to translation, rotation and scale and other imaging parameters.
- Choice of matching depends on the nature of the image and problem to be solved. There are two types of template or image matching approaches
  1. i. Template or Area based approach
  2. ii. Feature based approaches.

In the project work undertaken feature based approach is adopted. Feature matching approach extracts salient features such as corners in the two images and then establishes reliable correspondences. For this Normalized Cross Correlation(NCC) algorithm is used which is used in abroad range of computer vision tasks such as stereo vision, motion tracking , image mosaicking etc.,

Feature based method using NCC algorithm is simple and more accurate as the similarity measure is invariant with respect to brightness and contrast variations. This method is adopted since the hardware implementation is simple and it is useful for real time applications. In the project work undertaken only a single template can be matched at a time.

The proposed feature based method used in the project work is based on pixel by pixel manner and hence it significantly reduces the number of search pixels by using the composite detail sub image at low resolution level. The computation of correlation coefficients is only carried out for those high energy valued pixels in the composite detail sub-image(5).Sub-sampling and two stage matching techniques are adopted. In two stage matching advancement of the calculation result of first stage is taken to automatically convey the search for the second stage.

In practice, the template matching spends 224ms under the support of the largest image size. However, neither search window size nor processing speed is sufficient for real time applications; for instance, a surveillance system needs a search window of size 640x480 with 30 frame-per-second (FPS) performance. To cope with larger template size, a scalable architecture was proposed by Gupta [9]. The circuit can be expanded by cascading chips. The simplified NCC algorithm is implemented in to an NCC computation circuit which utilizes pipelined architecture and parallel computation with a view to reduce the chip area and computational cost. The proposed real-time matching module can perform real-time matching for template sizes ranging from 8 X8 pixels with respect to search window size 256X256 pixels.

II.METHODOLOGY

A. Method

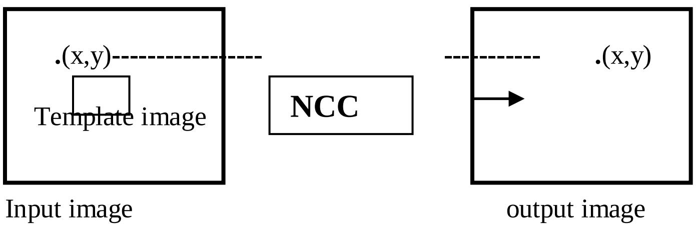

Fig.1 Overview of the template matching module.

The matching process moves the template image to all possible positions in a larger source image and computes a numerical index that indicates how well the template matches the image in that position. Match is done on a pixel-by-pixel basis.

B. Normalized Cross Correlation

The existence of low cost correlation hardware makes cross-correlation a very attractive operation. The cross correlation, provided that both the template and the Image neighborhood are suitably normalized. The most direct normalization is to divide each inner product by the square root of the energy of the template and the neighborhood. Mathematically, this can be expressed as

$$NCC = \frac{1}{N}\frac{\sum_{i=1}^{N}(s_i - s')(t_i - t')}{\sum\sqrt{\sum(s't')^2}} \qquad (1)$$

Where *s'* and *t'* are the means of samples s_i *and* t_i, respectively. The Mean is defined as:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i$$

(2)

In template matching the external parameters like brightness, noise and object position of image are considered. In order to overcome from this difference the mean of each pixel for best cross-correlation is calculated. During template matching , the template slides pixel-by-pixel in the search window to determine the most similar image block in the target image. A typical parameter of template matching approach is a threshold obtained on minimum correlation value yielding a valid match. This matching value allows for discriminating when an instance of the template is present or not in the image under examination. The ideal process of template matching is shown graphically in Fig.2 below

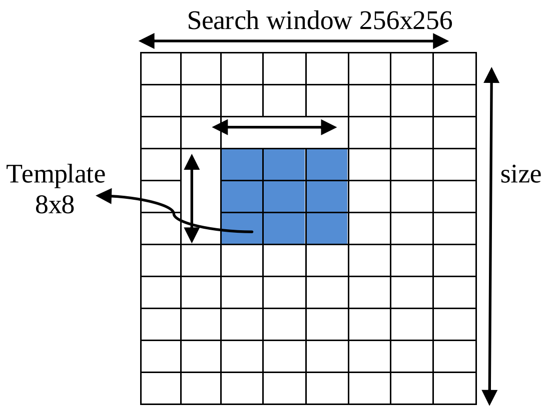

Fig2: Template selection

TABLE I

SPECIFICATION OF NCC CIRCUIT

Template image size	Min. template size	Max. template size
	3×3	256×256
Min. search window size	64×64	256×256
Max. search window size	640×480	
Computation time	‹5ms	

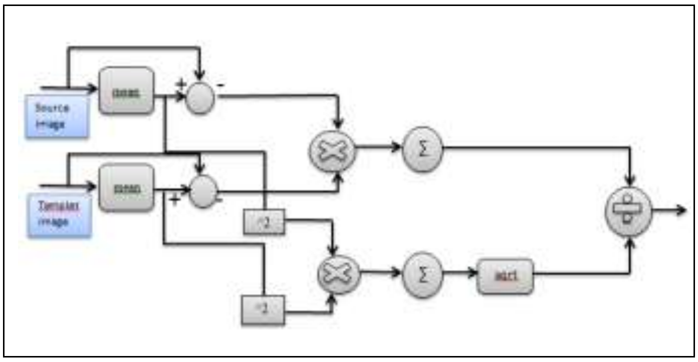

Fig 3 .Block diagram of NCC circuit

The Fig 3 shows the procedure how the actual template matching is performed. Correlation is a measure of the degree to which two variables agree, not necessary in actual value but in general behavior. The two variables are the corresponding pixel values in two images, template and source. The mean operation is performed on the source and the template image that is the pixel values are taken for evaluation. Based on the Normalized cross correlation equation the calculation is done. In the final stage the divider operator is been used to perform the comparison of both source and the template image. If the template matches with the source image then in the output the template image will be displayed otherwise the 0's that is represented by black spot will be recognized at the output. Since only the operators have been used the usage of area on the FPGA is substantially reduced which result in high computation speed (<5ms)for any size of search window and template image. To improve the throughput of circuit operation and reach the real-time requirement, the NCC circuit adopts full pipelined design that makes front-end and back-end circuits compute simultaneously. Moreover, the RAM controller employs a circular buffer structure to reduce RAM usage. The NCC algorithm is designed to find the maximum matching pixel or to its threshold level. The design is in such way that if matches are not found then that pixel is rejected for further process. When the pixel matches then it is stored in memory and pixel below threshold level is rejected and is considered here as zero. The process is continued from the top left of the image till to the end of target image for best matching with template.

III EXPERIMENTAL RESULTS

In this project work, the image data width is taken as input for both source and template image. The color image is converted into gray scale and then converted into text format (0's & 1's) in matlab. Xilinx software is used for coding NCC algorithm. The performance of the preferred NCC circuit is been executed in the PC with Intel Core i3 Processor@3GHz and 6GB RAM.

TABLE II specifies the platform used for the FPGA implementation with a speed of 100MHz.

The TABLE III shows the performance of the NCC Circuit in FPGA emulation. It includes the minimum and maximum template sizes which has been supported by the FPGA. The computation time of the circuit is been reduced by 50% compared to the circuit proposed in [3].

TABLE II

Speed	100MHz
Target platform	Xilinx Spartan3E

TABLE III

Performance of NCC Circuit

Speed	100MHz	
FPGA	Xilinx Spartan 3E FPGA	
Template image size	Investigated window size	FPGA emulation time(ms)
Same size investigated window		
256×256	640×480	1.02
64×64		4.63
64x64	256x256	0.611
8x8		4.06

The procedure of selecting the template image within the source image, conversion to text format of both source and template images, the hardware implementation output chipscope results and the retrieved template image in the target are shown below:

Step 1. First selecting the template image from the source image using matlab is shown in Fig.4 below:

Fig 4 : Source and selected template image

The Fig 4 shows the source and template selected with the text values those are the pixel values on which the NCC algorithm is performed.

Fig5 : Real time template matching module

Step2: The text values that is the pixel values obtained are fed into the spartan 3 kit shown in fig 5 where the NCC calculation is performed if the template image values are valid with the source image those values will be retained the unmatched part of the image will be 0's hence unmatched part will be eliminated.The values obtained after calculation the chipscope output is shown in fig 6

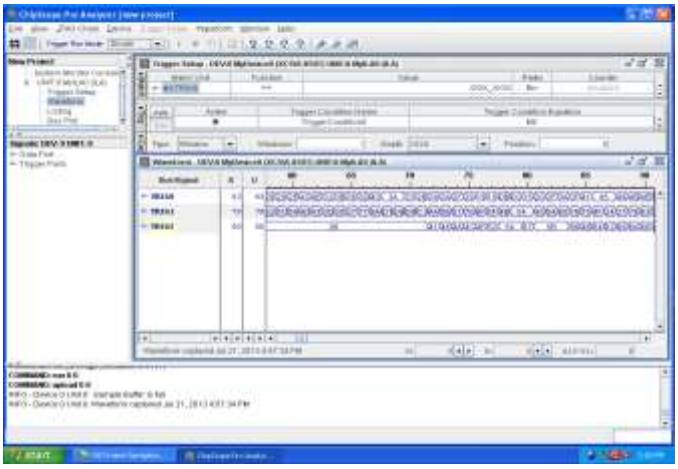

Fig 6 : Chip Scope output

Step 3: The values obtained in the chipscope are again fed to matlab code to get the exact location of template in the given image. The unmatched part is eliminated shown in fig 7.

Fig 7:Detected final output

The text values obtained are stored in temporary memory of the FPGA these values are fed into the matlab code to display the image and its position irrespective of the external parameters intensity and brightness levels. Fig 8 shows the final detected matlab output all three images , the source image ,the template image and the final output .

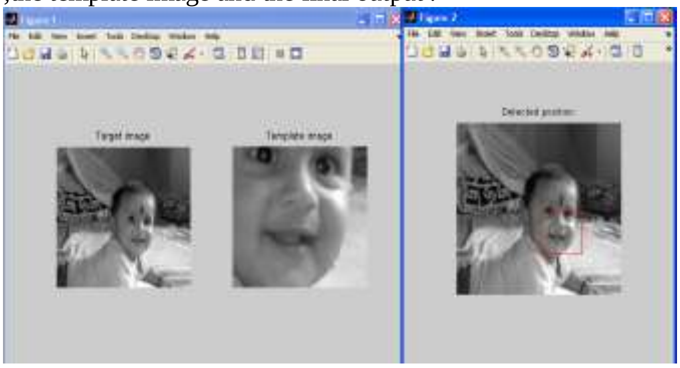

Fig 8: Template Matching Output Result in matlab

The simulation results for Template image 64×64. after performing template matching operation is shown in Fig 9, yield the output image.

Fig 9: Simulation results for template matching.

The device utilization of FPGA is shown in fig 10 (a)& fig 10(b)

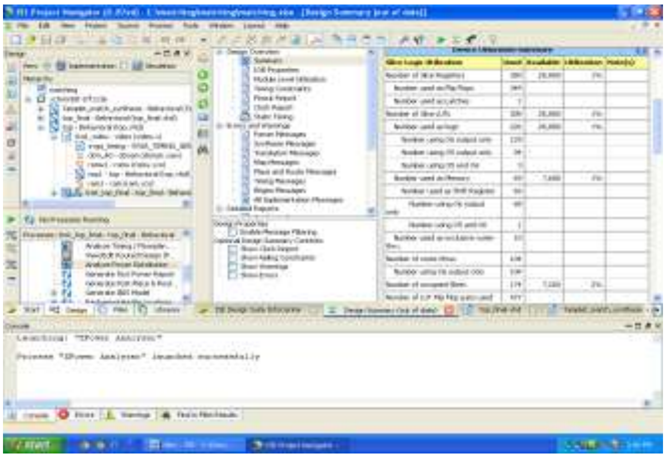

Fig 10(a): Device Utilization summary

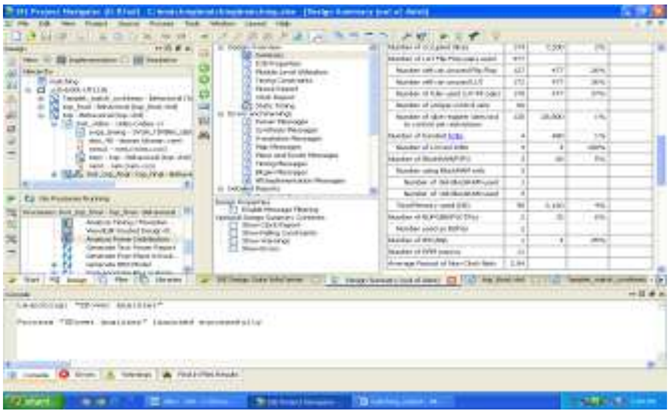

Fig 10(b): Device Utilization summary

The time required to image processing will be less for any kind of images.

IV CONCLUSION

A FPGA implemented template matching module which speeds up the time consuming normalized cross-correlation (NCC) template matching has been presented. Original NCC algorithm is modified to accelerate the computation speed of the circuit. Based on the algorithm a pipelined architecture has been developed with parallel processing unit which enchance the performance. Experimental results showed that our FPGA module results in less power consumption and hence the chip area is also been reduced. Furthermore, this module can also be applied to Automated vision applications such as object recognition, printed circuit boards , wafers face recognition etc.,

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